Correlating Tropospheric Column Ozone with Tropopause Folds: the Aura-OMI Satellite Data

Do we see tropopause folds in the Aura data?
Are the STE O_3 fluxes proportional to trop column anomalies?

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Thanks to the Aura ozone team

Methodology

- High resolution chemistry transport modeling (CTM) ($1^\circ \times 1^\circ \times$40-layer$\times$0.5-hour)
- Comparing with OMI level 2 ozone profile data
- Identifying tropopause folds and stratosphere-troposphere exchange (STE) from satellite data (as trop column anomalies)

Model setup

UCI CTM

Wind fields	ECMWF IFS in collaboration with U. Oslo
Horizontal Res	$1^\circ \times 1^\circ$ interpolated from T159 fields
Vertical Res	40-layer, surface – 2 hPa, $\sim$1 km near TPP
Time step	0.5 hour (3-hr averages for met-fields)
Trop Chem	ASAD (Carver et al., 1997)
Strat Chem	Linoz version 2 (Hsu and Prather, 2009)
Emission	EU QUANTIFY Y-2000 (Hoor et al., 2009)
Lightning NO_x	5.0 Tg N yr^{-1}

Aura ozone measurements

In ozone sonde data (and our model!), most folds occur between 150–300 hPa and are a little more than 1 km thick (about 50 hPa).

Instruments	Pressure (hPa)
MLS	215, 147, 100
HIRDLS	261–100 (11L)
TES	O_3 Columns (5 km $\times$ 8 km)
OMI	O_3 Columns (2600 km $\times$ 13 km)

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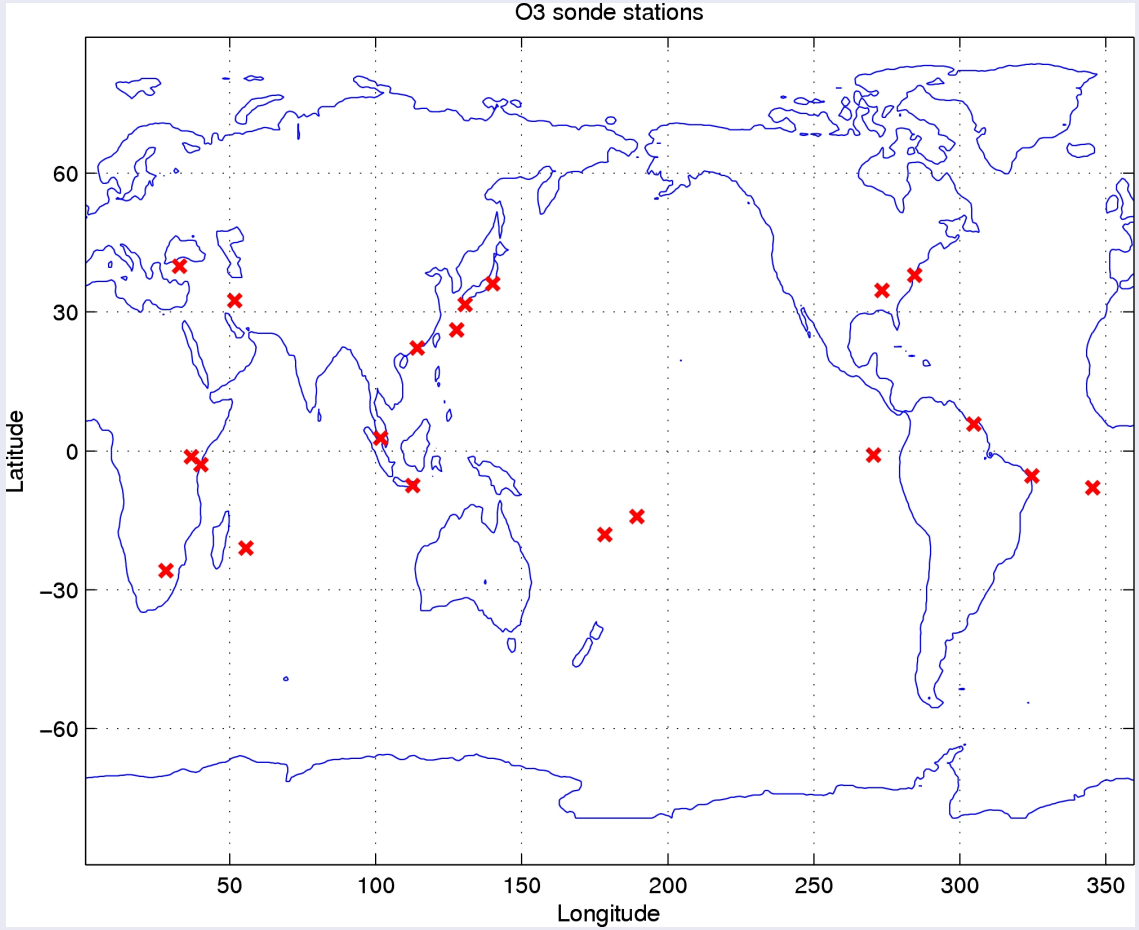
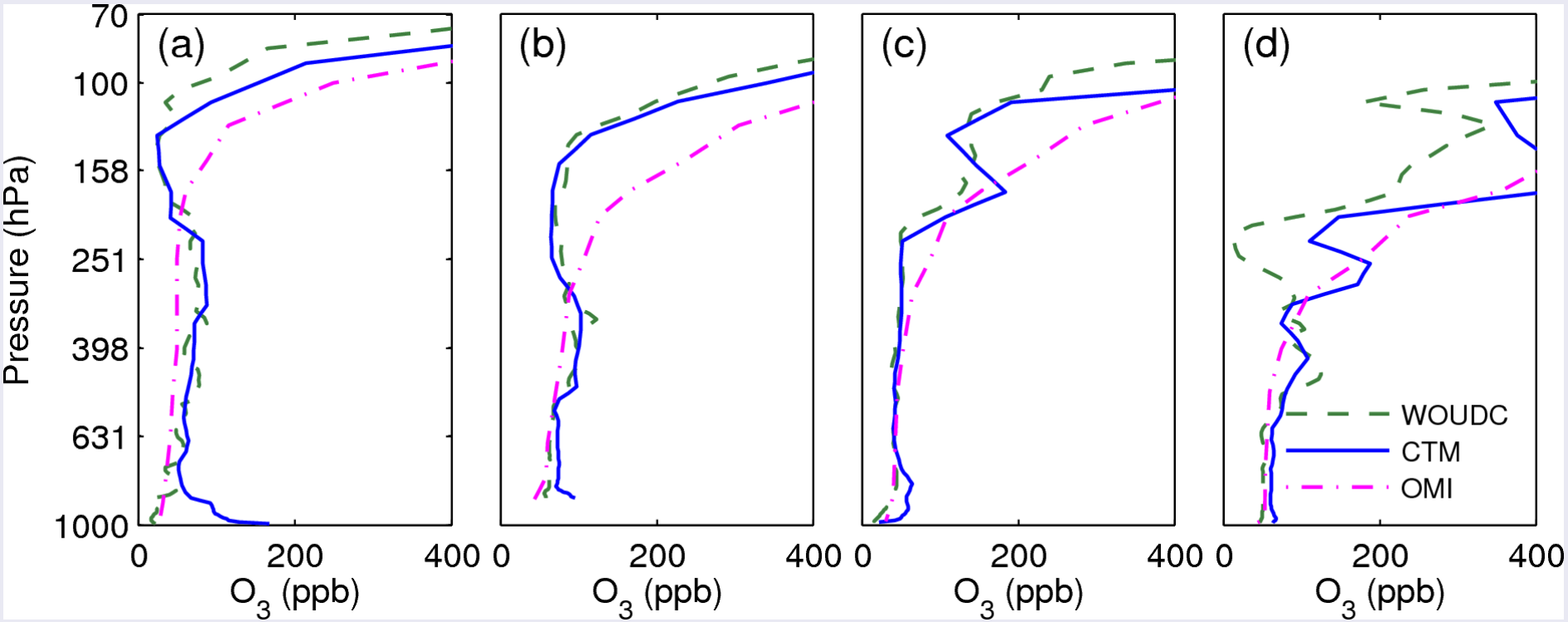
OMI L2 ozone profile (OMO3PR V003)	
Time	Oct 1, 2004 – present
Horizontal	13 km$\times$48 km (profiles) 13 km$\times$24 km (columns)
Vertical	18-layer, surface – 0.3 hPa

CTM vs. Sonde

Searching for TFs: 35°S – 40°N (where most folds occur), 20 WOUDC stations, 638 exact matches in year 2005.



CTM vs. Sonde



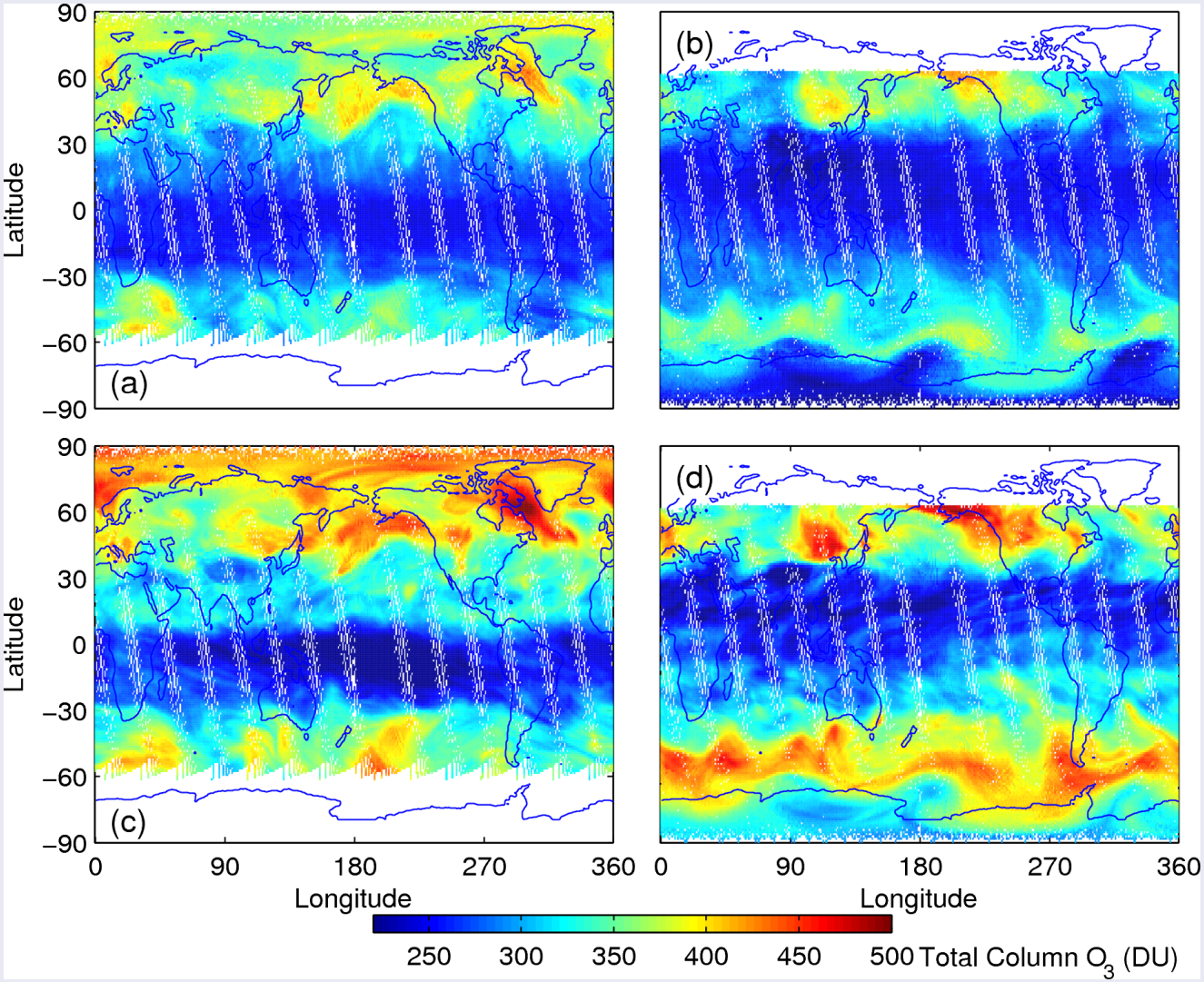
(a) 25% Hong Kong, China (22.31° N, 114.17° E, STN 344), Sep. 7, 2005.
(b) 25% Ankara, Turkey (39.97° N, 32.86° E, STN 348), Aug. 17, 2005.
(c) 30% Huntsville AL, USA (34.72° N, 86.64° W, STN 418), Dec. 3, 2005.
(d) 20% Huntsville for Mar. 5, 2005.

Swath-by-swath comparisons

Deriving tropospheric column O_3 (TCO)

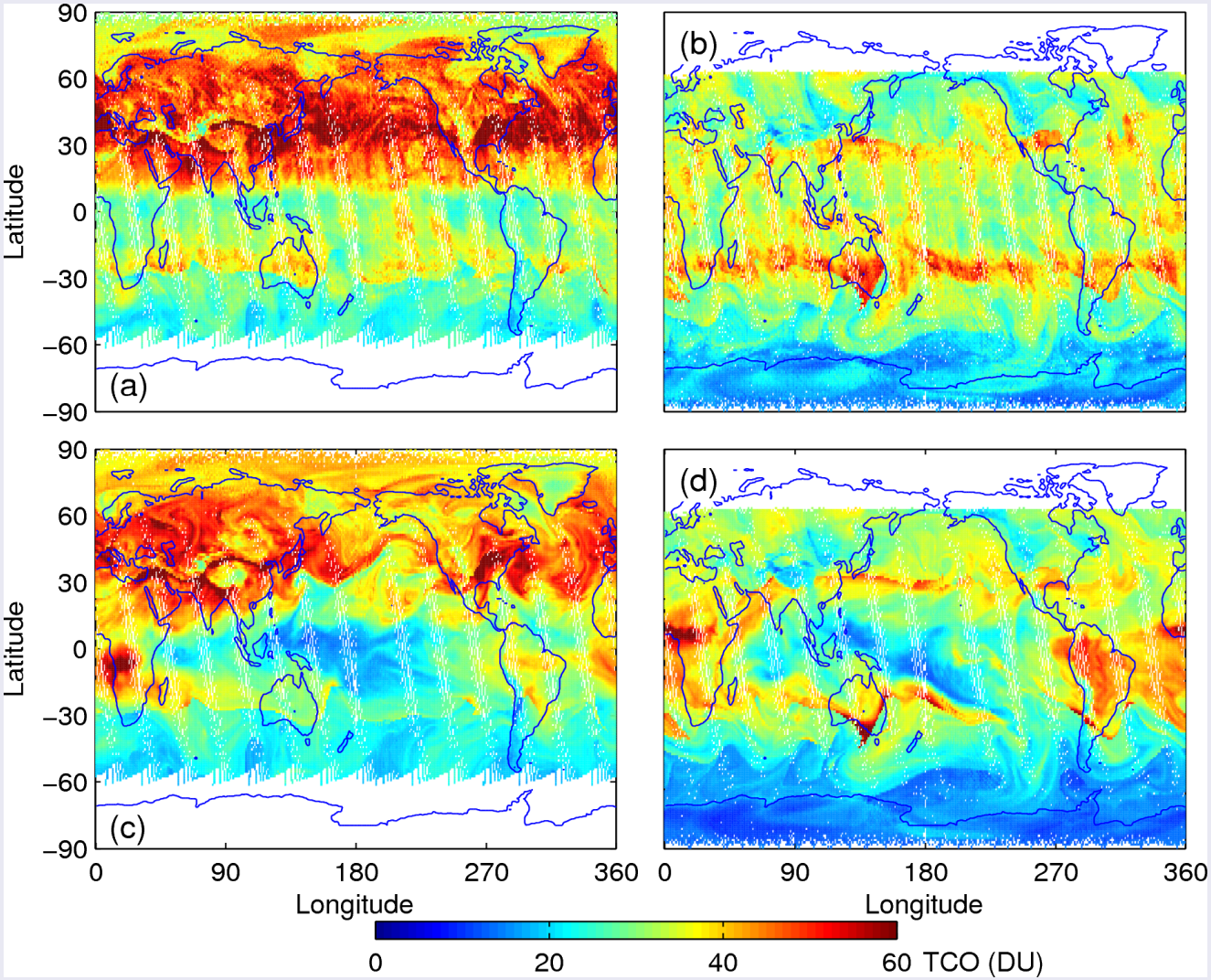
- Tropopause (TPP) is the upper boundary of the uppermost CTM layer identified as tropospheric by its mean *e90*-tracer abundance.
- OMI TCO is calculated from the OMI O_3 profile with CTM TPP.

Swath-by-swath comparisons: total column



Swath-by-swath comparison of total column O_3 (unit: DU) from OMI (top) and CTM (bottom) for June 10, 2005 (left) and December 3, 2005 (right) (25-hr periods beginning 00 UTC).

Swath-by-swath comparisons: tropospheric column



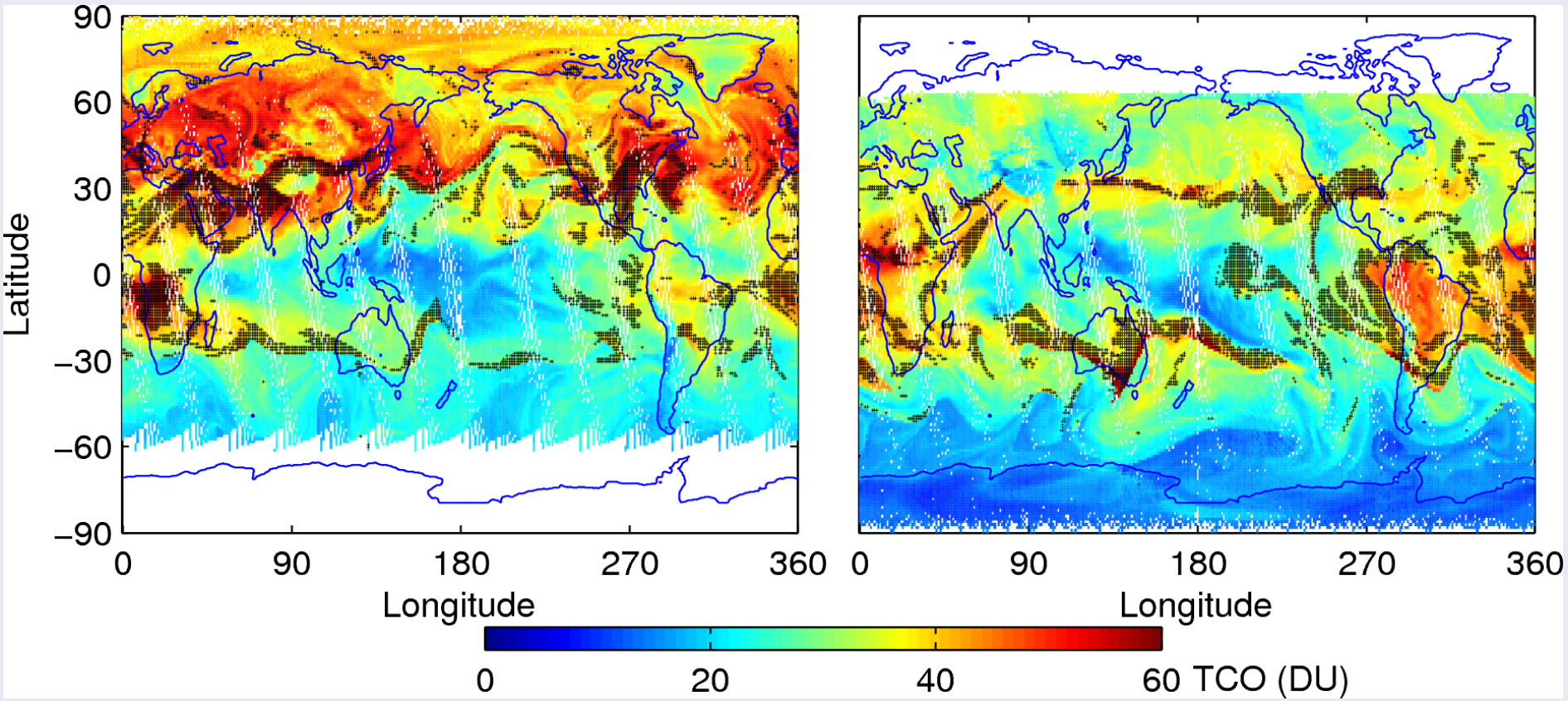
Swath-by-swath comparison of tropospheric column O_3 (unit: DU) from OMI (top) and CTM (bottom) for June 10, 2005 (left) and December 3, 2005 (right) (25-hr periods beginning 00 UTC).

Detecting tropopause folds (TF) in the CTM

Objective criteria for TF (2M per month)

- Above 5 km
- Once the O_3 exceeds 80 ppb
- Within 3 km above, decreases by 20 ppb or more to a value below 120 ppb

TF location relative to TCO for Jun. and Dec., 2005

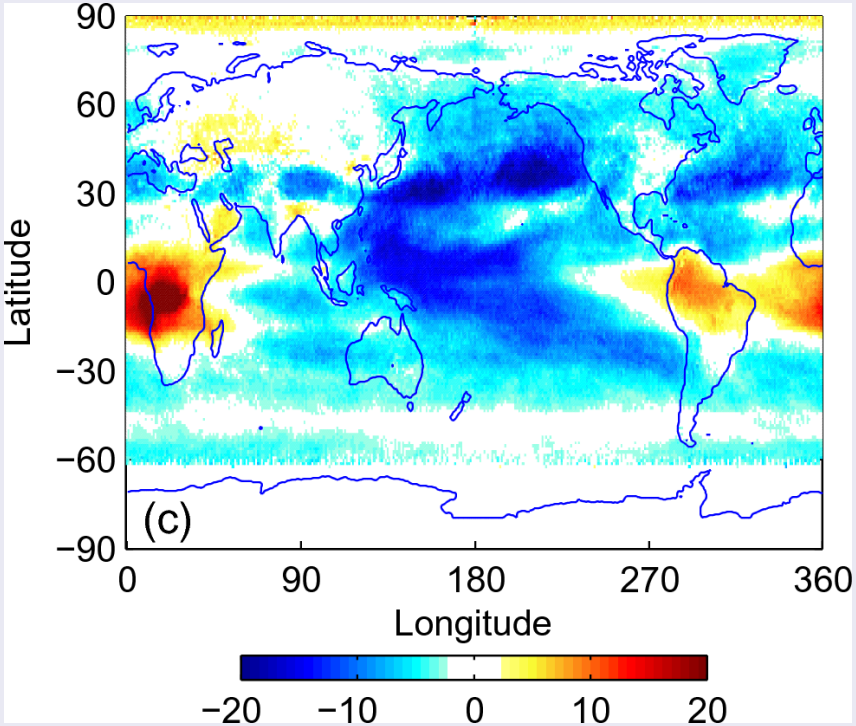


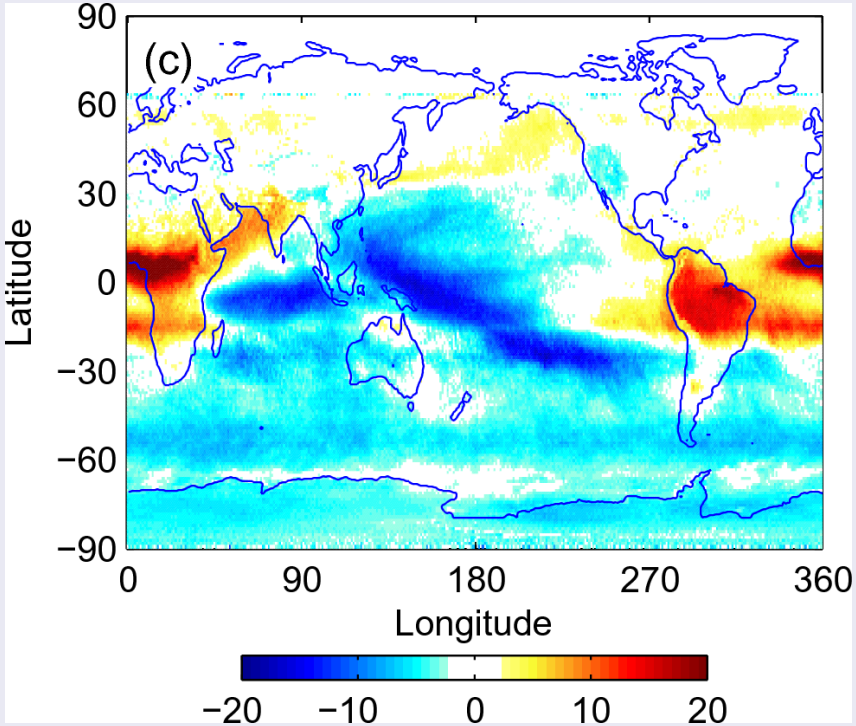
CTM TCO (color, unit: DU) and TF events (black “+”)

for Jun. 10 (left) and Dec. 3 (right), 2005 (25-hr periods beginning 00 UTC).

Variability and Bias in TCO

Monthly mean diff.: CTM-OMI (DU) for Jun. and Dec., 2005

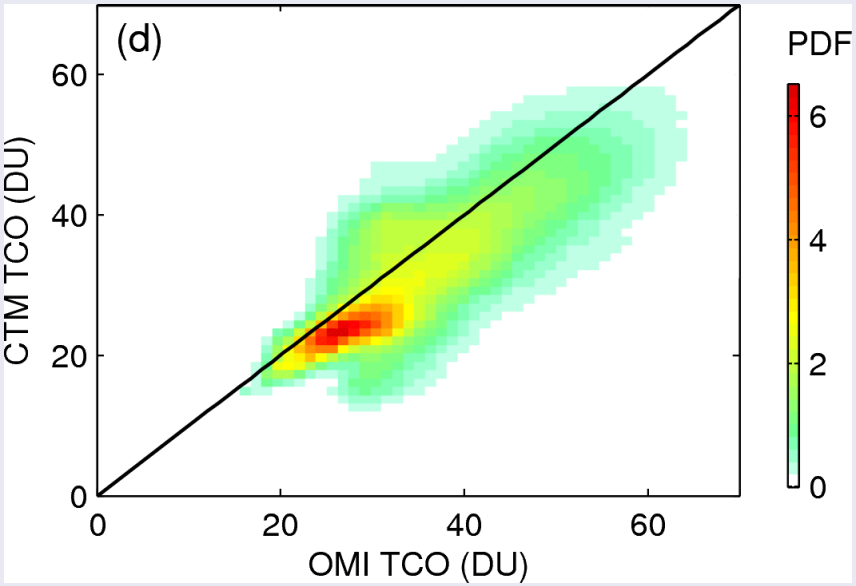


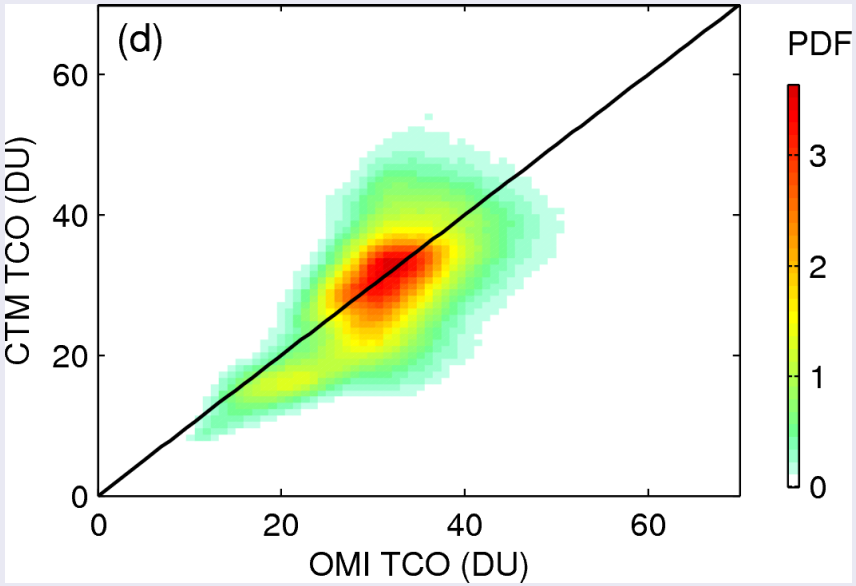


For most of the daylit globe (56 % in June and 65 % in December), the differences are within ± 5 DU.

Variability and Bias in TCO

CTM vs. OMI probability distributions for Jun. and Dec., 2005

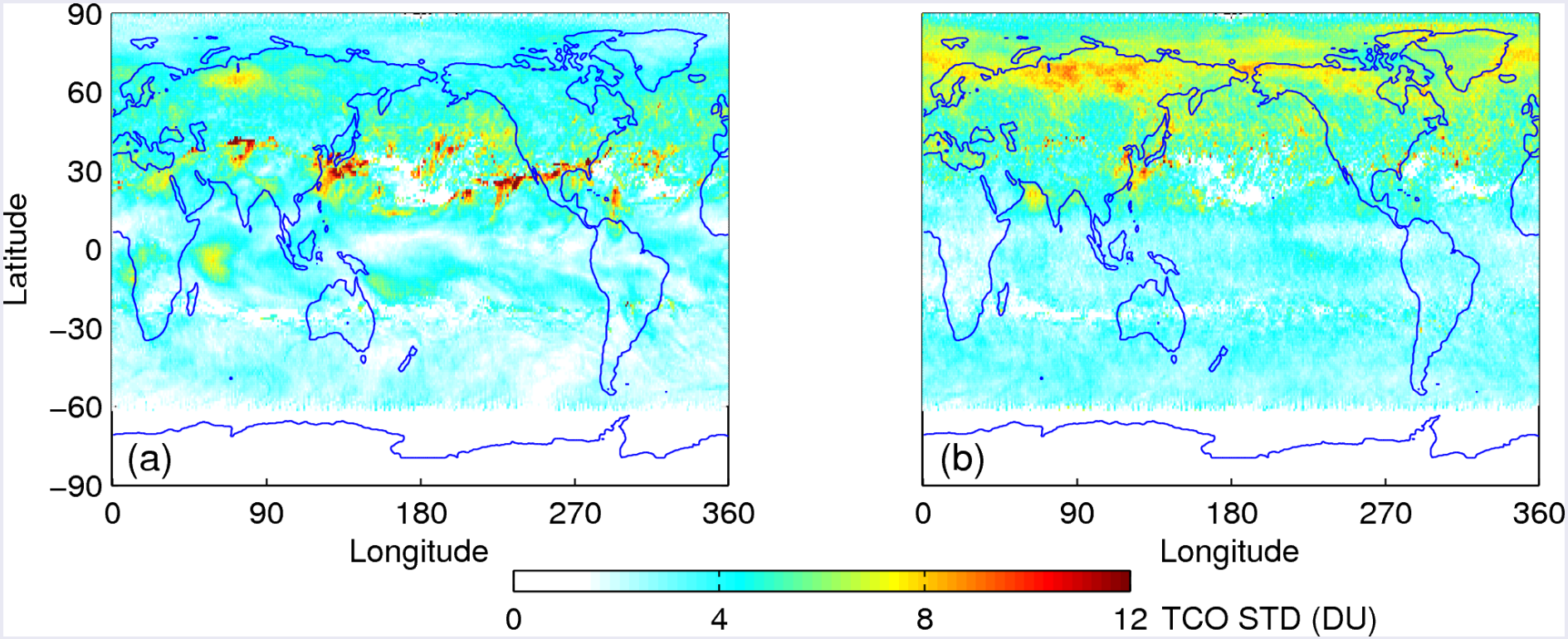




Two million comparisons per month. The highest densities lie along the 1:1 line (black bold line) and errors are generally symmetric, showing little overall bias. Units are 0.001 per DU^2.

Variability and Bias in TCO

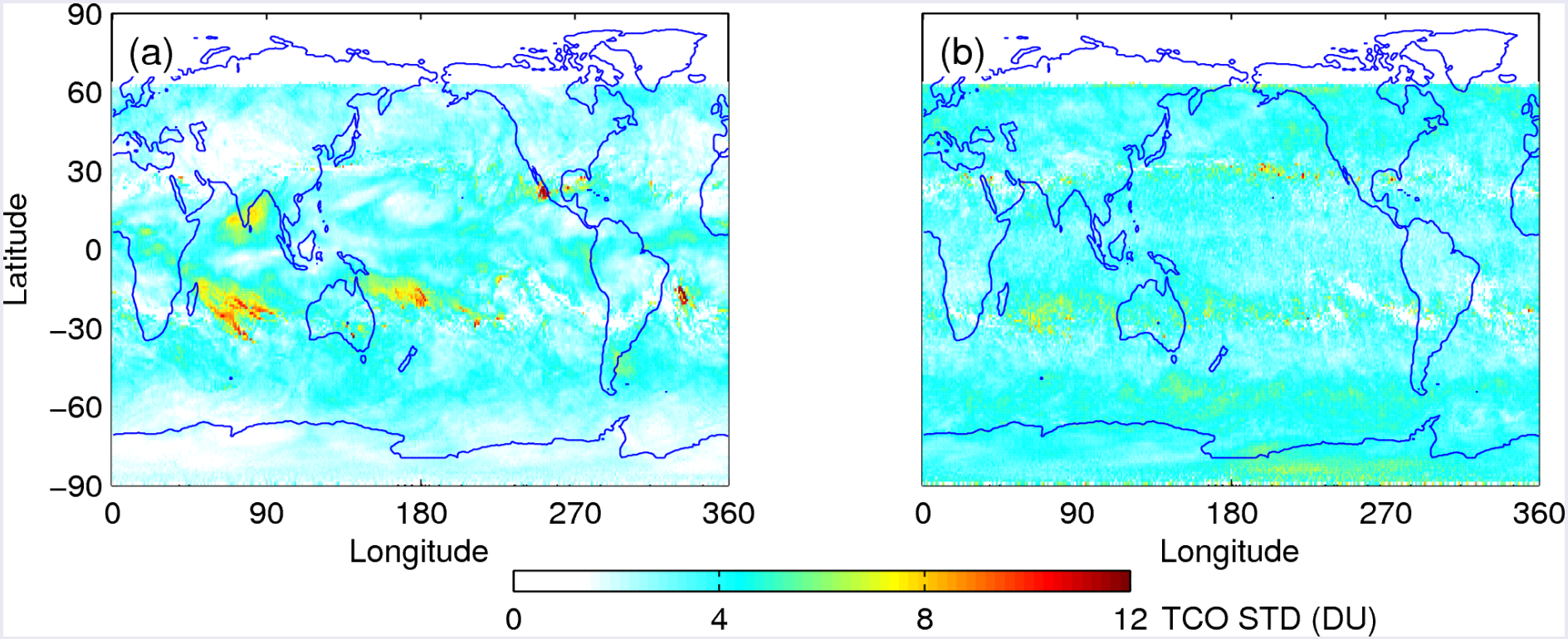
TCO standard deviation (σ, DU) of CTM and OMI for Jun., 2005



Data filtered to aviod intermediate tropopause (102–181 hPa (13%))

Variability and Bias in TCO

TCO standard deviation (σ, DU) of CTM and OMI for Dec., 2005



Data filtered to aviod intermediate tropopause (100–185 hPa (13%))

Variability and Bias in TCO

Does the CTM simulate the hourly variance in the OMI?

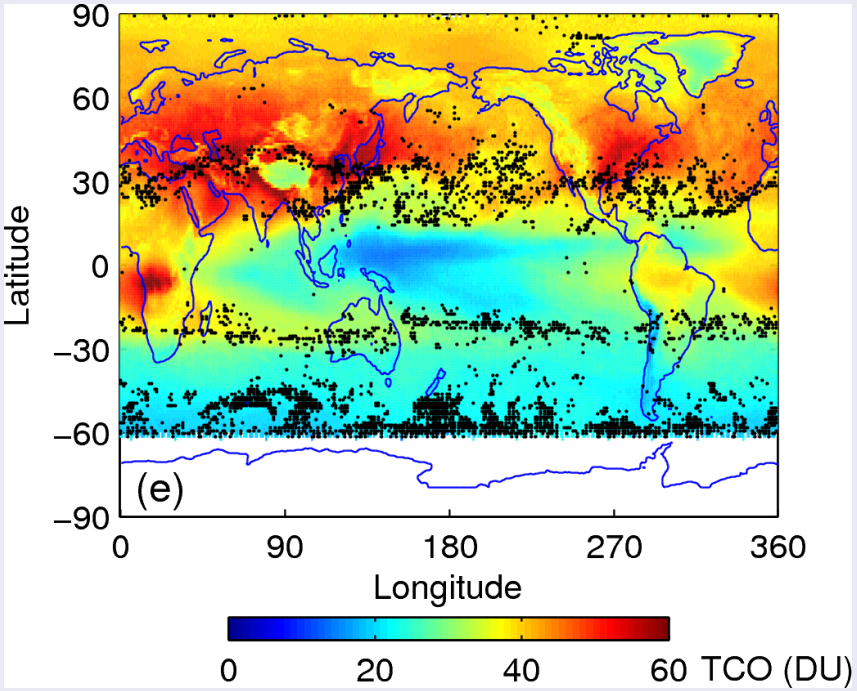
$$\text{Simulated Variance}: \quad SV = 1 - \frac{\overline{(CTM' - OMI')^2}}{\sigma^2_{CTM} + \sigma^2_{OMI}} \tag{1}$$

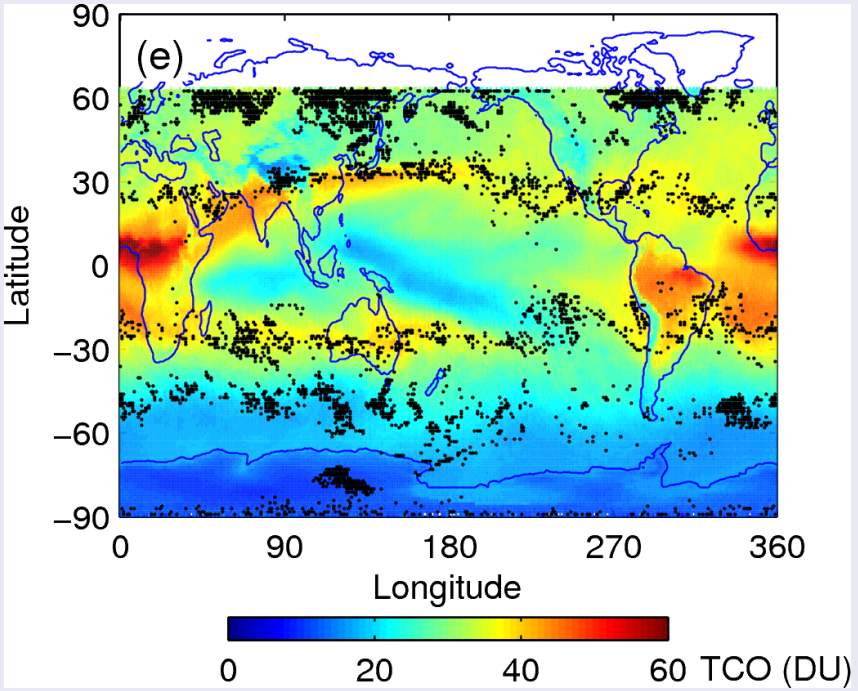
where $CTM' = CTM - \overline{CTM}$ and $OMI' = OMI - \overline{OMI}$.

- SV measures the fraction of variance that is accurately simulated.
- SV ranges from negative (when CTM' and OMI' are anti-correlated) to +1 (when CTM' and OMI' are identical).
- The mean SV are 0.29 (tropics) and 0.34 (extra-) for June, and 0.21 (tropics) and 0.39 (extra-) for December.

Variability and Bias in TCO

CTM matches OMI (SV $\geq$ 0.70) for Jun. and Dec., 2005

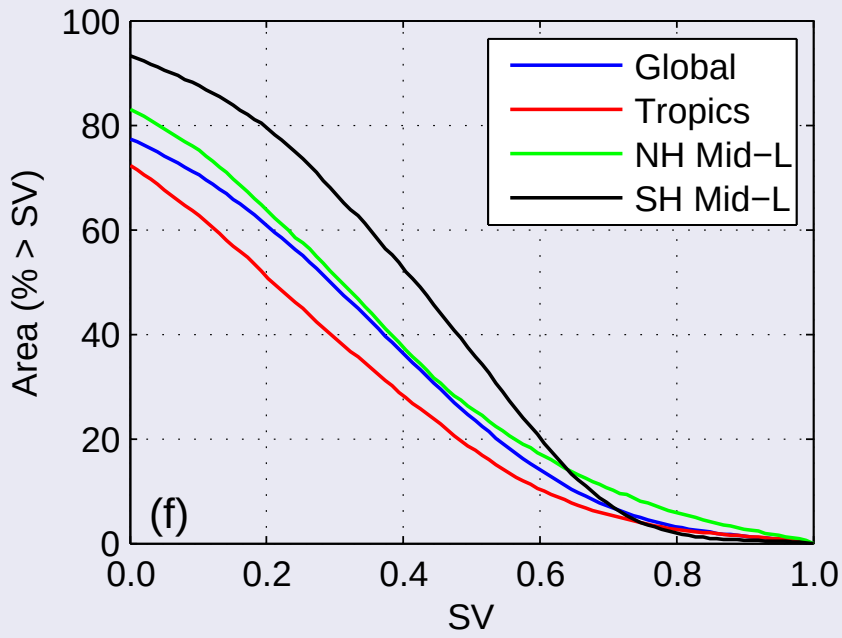


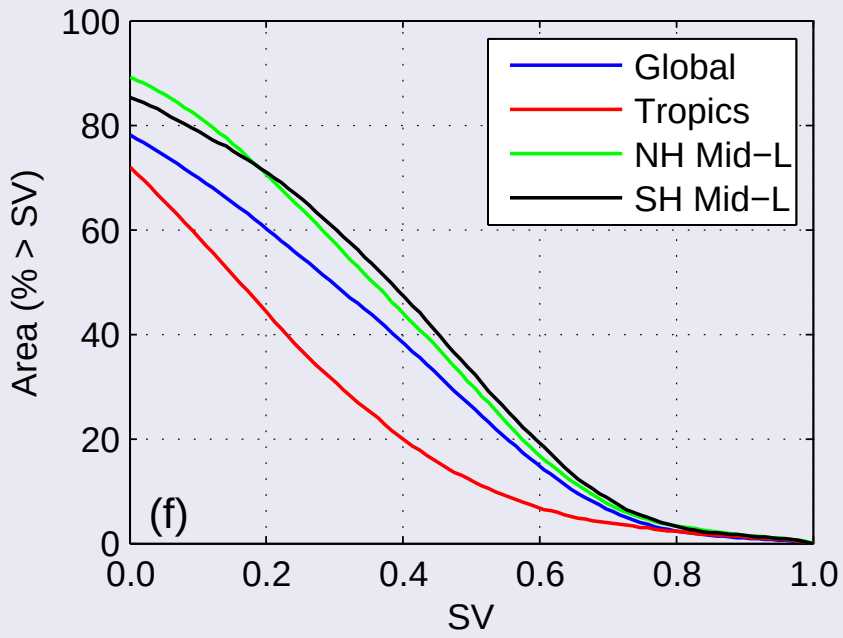


On top of the CTM TCO (color), areas with SV $\geq$ 0.70 are marked by black dots. Because of the tropopause filter, TCO variance is not affected by the tropopause motion.

Variability and Bias in TCO

Cumulative distributions of SV for Jun. and Dec., 2005

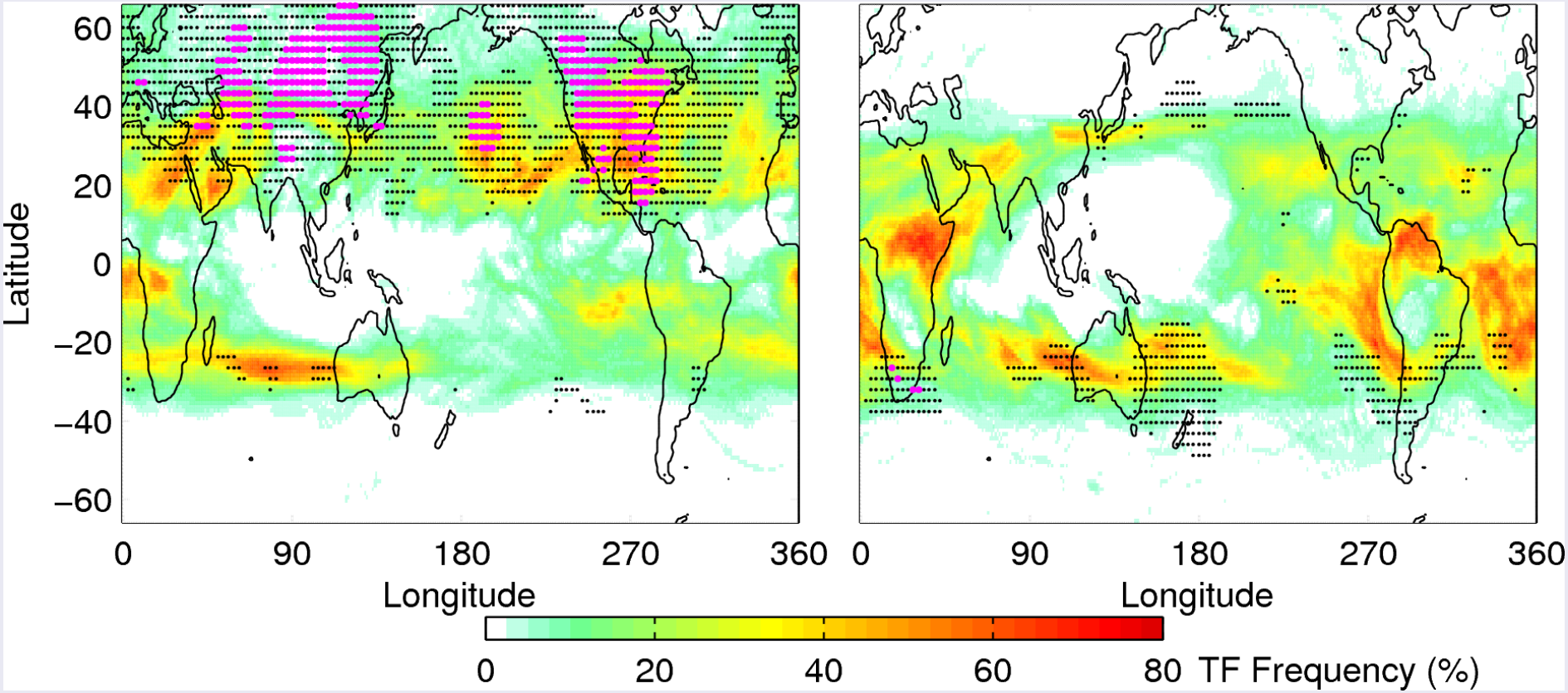




Independent of seasons, the SV is best in SH mid-latitudes, moderate in NH mid-latitudes, and worst in the tropics. Overall, SV $\geq$ 0.50 for about 35 % of the mid-latitudes.

TF and STE O_3 Flux in CTM for Jun. and Dec., 2005

TF frequency (color) vs. STE flux (stippling)



Over the summer, approximately 5 % of continental convection in the CTM reaches O_3 levels above 120 ppb.

Conclusions

- Comparing the CTM profiles with ozone sondes reveals that the model matches sonde measurements and is capable of locating and resolving tropopause fold events.
- In the CTM, large daily variance in TCO are correlated with TF events and occur most frequently near the subtropical jet streams.
- The modeled ozone columns show very good agreement with coincident high frequency OMI observations, both in terms of the monthly mean and variability. Results are generally better in extra-tropics than in tropics.
- The STE flux in the vicinity of the subtropical jets can possibly be measured with TCO anomalies.